Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin

Designing Personal Heating Wearable Devices for Limbs' Coldness

Presenter: Zaynab Salman
Supervisor: Dr. Gavin Doherty
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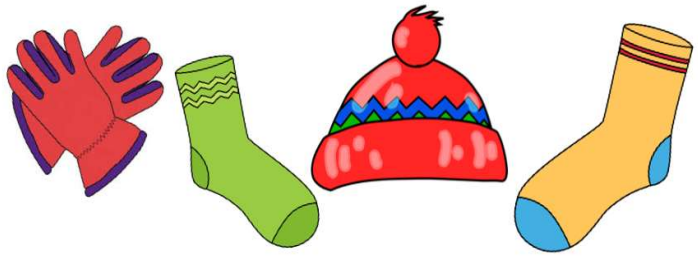
Background

- Cold intolerance is a syndrome associated with a range of medical conditions in which poor blood circulation or body temperature control is a problem. People with limb coldness experience pain, discomfort, and negative impacts on their quality of life.
- Cold Intolerance is common symptom among several diseases [1,2,3,4,5].
- Some of these diseases could treated by different types of medicine and others by Self-Management [6,7,8,9,10,11].



Diseases - Cold limbs Symptom

- Diabetes
- Polio
- Raynaud's Phenomena
- Motor Neuron Disease
- Parkinson’s Disease

Polio & cold limb

Disease	Clinical Diagnose	Impact of patient's life	Treatment
Polio	Positive for 65% -80% polio survivors	- Sever burning pain - Combined by Hyperesthesia, needle pins sensation, and skin color change[35]. - Unpleasant	Self-Management

Polio participants in workshop

We explored the impact of limb coldness on quality of life through:

- The strategies used by participants to manage limb coldness.
- Investigated issues surrounding the design of personal wearable technologies to support people with cold limbs.

Cold Limb & Quality of life

The impact of cold limb syndrome on the quality of life of participants is presented under three main themes, summarised in Table1, the coping strategies also classified under four main themes summarised in Table2. The other issues discussed in the participatory workshop detailed in Table3 and 4.

Table 1 Sub-themes of Quality of Life

Themes	Sub-Theme	Codes
Quality of Life	Feelings	Steel cold, painful, severe cold, freezing, uncomfortable, swelling, embarrassing
	Inability to do things	Weekend shopping, I cannot grip my cards, I cannot carry my bags, prevents me from going out, difficult to put on and take off, going to the toilet is difficult wearing two pairs of trousers.
	Lifestyle	Wearing different sizes of shoes, wearing two trousers, staying indoors until they feel warm, time consuming, heavy clothes in Summer.

Table 2 Coping Strategies and examples

Strategies	Examples
Wearable sources of heat	• Warm clothes • Clothes covering extremities (long socks, gloves) • Extra layers of clothes (e.g. "2 pairs of trousers or leggings") • Warm clothes adapted to the use of caliper or wheelchair • Thermal clothes (e.g. thermal long-sleeved tops, underwear) • Heat-maintaining shoes (e.g. "sheep skin boots") • Leg warmers
Non-wearable sources of heat	• Electrical device (e.g. heating pads, electric blanket) • Heat emanating from hot water (e.g. water bottle, bath) • Addition heaters
Behaviour and modifications	• Avoid sources of cold (e.g. air drafts) • Change posture (e.g. elevate feet) • Exercise (e.g. swimming, keep standing, stimulate muscles) • Consume hot or heat-inducing beverages (e.g. tea, alcohol) • Adjust environmental temperature (e.g. use home/car heating system) • Adapt shoes for extra layers of clothes (e.g. XL slippers)
Therapeutic help	• Biochemical treatment • Heating patches (e.g. "VERSATIS thermal Patch") • Physiotherapy

Table 3 Participant strategies, sub-themes, advantages and disadvantages

Strategy	Sub-Themes	Advantages	Disadvantages
Wearable sources of heat	Feelings	Protective, warm, comfortable, avoid stigma (don't feel different from other people)	Uncomfortable, overheating, sweating, awkward
	Usage	Used on a daily basis, comes with zip to make it easy to wear, can have them all the time	Surgical appliances, large size so they won't come off easily, different sizes for each layer, not easy to get them on/off, don't cover feet and hands, don't go down to the feet, not tailored for one limb, buying double pairs to fit
	Cost	Cheap (for some participants)	Expensive, double cost
Non-wearable sources of heat	Feelings	Increase body temperature, relieve pain and cold, feel warm, keeps warm, feel better	Leads to sweating , sometime not working to warm up the legs despite of keeping it long time on
	Usage	Could use it every day, reusable	Cannot use them all the time, don't last for long time, could leave on for only 15 minutes, could use indoor only
	Cost	Worth the expense	Expensive, good ones expensive

Table 3 Participant strategies, sub-themes, advantages and disadvantages

Strategy	Sub-Themes	Advantages	Disadvantages
Behaviour and Modification	Feeling	Feel better, Immediate relief	Doesn't work all the time, get cold very fast, doesn't work for some due to mobility issues
	Usage	Could be used to avoid coldness	Can't do it all the time
	Cost	Cheap	Expensive
Therapeutic help	Feelings	Relieve pain, better sense of heat, feel better	Relieving pain depending on the quality of service
	Usage	Could be use to sense immediate increase of temperature	Can't use it all time,
	Cost	Worth the cost	Expensive

Table 4 Coding and Themes of Design Issues

Themes	Sub-themes	Codes
Look and Feel	Material	• Heat generation (e.g. the fabric itself should generate heat) • Integration of heating device (e.g. heating pads embedded into fabric) • Solidity (e.g. strong material) • Safety (e.g. if on feet, should provide a good grip)
	Look and Feel Form	• Limb coverage (e.g. full-length socks) • Variety (e.g. covers extremities, trousers or legs)
	Position on the body	• In direct contact (e.g. attached to feet) • Integrated into clothing (e.g. incorporated into lining of caliper) • Heat propagation (e.g. spread warmth from the feet)
	Compatibility with clothing	• Variety (e.g. available in different colors) • Size (e.g. should fit into regular-size clothes/shoes)

Table 4 Coding and Themes of Design Issues

Themes	Sub-themes	Codes
Design and control	Features	• Long-life battery (e.g. rechargeable), Convenience (e.g. wireless, detachable, chargeable while in use) • Remotely controllable (e.g. with smartphone) • Adapt temperature to body (e.g. read body temperature or allow personalisation) • Balanced degree of automation
Physical properties	Mobility	• Light material • Balanced thickness (e.g. not too big but still accessible) • Mobile control device

Results and Conclusions

Millions of people worldwide are living with cold intolerance, a syndrome which has no medical cure. It affects their quality of life because it is painful and discomforting, and inhibits daily activities. With developments in technology there is a potential to contribute to wearable solutions for mitigating limb coldness. For this project we focussed on people with post-polio syndrome, in which limb coldness is a prominent feature. Two user-centered design workshops were conducted for polio survivors, all of whom suffer from cold limb syndrome. The results of these workshops showed that the participants are using common strategies and commercially available heatable devices such as electrical blankets and microwave-heatable devices to cope with limb coldness.

Results and Conclusions

All of the strategies have advantages and disadvantages, and none are without disadvantages. Users adopt strategies according to their changing needs and they are not always successful. Participants were open to the use of wearable devices for limb coldness including both heated elements and sensing, however they variety of manifestations of limb coldness, issues with body size, stigma, and practical issues such as charging need to be considered in the design of such devices. This research shows that the cold limb syndrome has a huge impact on a patient's quality of life and that there is a clear need to develop appropriate, affordable, wearable technology-based solutions to their cold limb problem.

Results and Conclusions

Most of the relevant literature discusses heatable materials, temperature sensors, and wearable devices but independently of cold limb syndrome. Therefore, this research comprises a first exploration of the design of wearable technologies in the context of cold intolerance. The work aims to contribute to the development of practical, viable solutions to improve the quality of life of individuals impacted by cold limb syndrome

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Thank You